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(54) MODIFYING METHOD AND APPARATUS FOR FLY ASH

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(72) Inventor	Kyoichi SHIBUYA 18-29 Matsudo Nitta, Matsudo-shi	(72) Inventor Akio KAWASHIMA Kamagatani Corporus M-304 448-1 Kamagatani, Kamagatani-shi
(72) Inventor	Hideki ARAI 3-7-2-105 Tsudanuma, Narashino-shi	(71) Applicant Sumitomo Cement Co., Ltd. 1 Kanda Mitoshori-cho, Chiyoda-ku, Tokyo
(72) Inventor	Kiyoshi ONO	(74) Representative Attorney Akira TSUCHIBASHI

## SPECIFICATIONS

1. Title of the Invention

## MODIFYING FOR FLY ASH

Scope of Patent Claims

(1) A method for modifying fly ash wherein: the fly ash discharged from a coal boiler is classified into coarse particles, medium particles and fine particles; the coarse fly ash that contains a large amount of unburned particles is used as a substitute fuel and the fine fly ash that contains few unburned particles is used as a fine powder; the fly ash that was classified as medium is further classified into fine particles and ultra-fine particles; the fine fly ash that contains few unburned particles is used as a fine powder; the ultra-fine ash with more unburned particles is once again combusted in the modifying apparatus and the unburned particles are removed; and this is used as a fine powder.

(2) A method for modifying fly ash as claimed in Claim 1, wherein: within the modifying apparatus, waste heat from the clinker cooling unit of the cement burning plant or external air is drawn in and used as the combustion air for the ultra-fine fly ash.

(3) A method for modifying fly ash as claimed in Claim 1, wherein: the exhaust gas discharged from the combustion apparatus is used in preheating the material within the cement burning process.

(4) An apparatus for modifying fly ash, wherein: it has a mixture chamber and a combustion chamber; there is a primary air current furnace wherein the jet air duct and the swirl air duct have been connected in order to draw the air for fly ash combustion into the lower terminus; there is a secondary air current furnace that is connected to the exit side of the primary air current furnace in order to re-combust the fly ash discharged from the primary air current furnace that is constructed in the same manner as the primary air current furnace; and there is a division circulation apparatus that is located between the primary and secondary furnace or within the air-mixing chamber of each furnace, and this is used to circulate one part of the fly ash combusted within the primary air current furnace and/or the secondary air current furnace in the primary air current furnace and the secondary air current furnace, or [circulate it] into the primary air current furnace.

(5) An apparatus for modifying fly ash as claimed in Claim 4, wherein:

the jet air duct and the swirl air duct are connected to the clinker cooling apparatus of the cement burning plant via the combustion air supply duct.

- (6) An apparatus for modifying fly ash as claimed in Claim 4, wherein: the jet air duct and the swirl air duct are connected to the external air drawing apparatus via the combustion air supply duct.
- (7) An apparatus for modifying fly ash as claimed in Claim 4, wherein: at least one part of the exhaust duct in the apparatus is formed through a connection to the appropriate location on the suspension preheater of the cement burning plant.

### 3. Detailed Explanation of the Invention

This invention relates to a method and apparatus for modifying fly ash within the discharge gas of a fine-powder coal boiler.

In recent years, energy conversions from oil to coal have proceeded rapidly in line with the rising costs of oil, and even in boilers in thermal power plants, conversions from oil to fine-powder coal have been performed. The coal ash discharged from the boiler can be removed in the initial fusion state, but the ash can change into spherical particles due to surface tension, and can harden to become fly ash, which has been used in fly ash cement.

However, in recent years, pollution control regulations have become more stringent, and as there is a requirement to reduce the amount of nitrogen oxides (NO<sub>x</sub>) in particular, two-stage combustion or NO<sub>x</sub> reducing methods such as exhaust gas recirculation have come to be used as the combustion method in boilers, and as a result, unburned particles remain within the fly ash, leading to a degradation of the fly ash characteristics. In other words, when using this sort of fly ash that contains a large amount of unburned particles in fly ash cement, the cement can turn black, or there may be adverse affects such as a reduction in strength, which means that the fly ash cannot be used as is. Further, it has been estimated the amount of fly ash generated will be 3,500,000 tons at the end of 1985, and therefore, it is necessary to have a treatment method for fly ash that is generated in large-scale amounts. Studies into technologies in the domains of cement, aggregates, construction materials and civil engineering have made progress, but in the case where there is a large amount of unburned particles within the fly ash as described above, this can have adverse affects on the

raw materials, and therefore, fly ash containing few unburned particles has been demanded from a wide variety of fields.

As a means of removing the unburned particles from within the fly ash, the method used is generally one where the unburned particles are re-combusted, but in order to perform heat treatment on the entirety of the fly ash generated in a large-scale operation, a large amount of fuel must be consumed in this combustion, leading to poor combustion efficiency. Further, not only is the volatility of the unburned particles within the fly ash low, they are also partially turned into graphite, and so the pace of combustion is slow and the accumulation period within the modifying apparatus will be longer. The size of the apparatus must therefore also increase, which is uneconomical.

This invention was established with the above issues in mind, and has the goals of greatly reducing the unburned particles by classifying the fly ash discharged from the fine-powder coal boiler, and along with greatly reducing the fuel needed in the combustion of these unburned particles, aims to effectively use this fly ash.

The fly ash method according to this invention is one wherein: the fly ash discharged from a coal boiler is classified into coarse particles, medium particles and fine particles; the coarse fly ash that contains a large amount of unburned particles is used as a substitute fuel and the fine fly ash that contains few unburned particles is used as a fine powder; the fly ash that was classified as medium is further classified into fine particles and ultra-fine particles; the fine fly ash that contains few unburned particles is used as a fine powder; the ultra-fine ash with more unburned particles is once again combusted in the modifying apparatus and the unburned particles are removed.

The amount of unburned particles within the fly ash depends on the boiler operational conditions as well as the type of coal and the grain size, but is generally in the range of 5-15%. Of this amount, the fly ash that can be used in fly ash cement is generally 5% or less of the unburned particle amount. Further, it is preferable to use the part with the higher unburned particle amount as the ash that can be used as a substitute fuel. With this point in mind, the examples of embodiment according to this method classify the fly ash into the ranges of coarse, medium and fine, as shown in Table 1.

Table 1

	Particle Diameter ( $\mu\text{m}$ )	Unburned Particles (%)
Fly ash discharged from the boiler	$d = 30$	7.9
Classified fly ash	$d > 149$	48.2
	$44 \leq d \leq 149$	13.4
	$d < 44$	2.6

According to the results shown in Table 1, the average particle diameter of the fly ash discharged from the coal boiler is approximately 30  $\mu\text{m}$ , containing 7.9% unburned particles. When this has been classified into diameters of 44  $\mu\text{m}$  and 149  $\mu\text{m}$ , the unburned particles within the fine fly ash of particle diameter 44  $\mu\text{m}$  amount to 2.6%, and the unburned particles within the coarse fly ash of particle diameter greater than 150  $\mu\text{m}$  amount to 48.2%. Therefore, not only is it possible to use the fly ash of particle diameter less than 44  $\mu\text{m}$  as is in the fly ash cement where an unburned particle amount of less than 5% is needed, but it is also possible to use the coarse fly ash of particle diameter 150  $\mu\text{m}$  or greater for which the amount of unburned particles is high at 48.2% as a substitute fuel. When the ash has been classified in this way to 44  $\mu\text{m}$  and 149  $\mu\text{m}$ , the amount of medium fly ash that is 44  $\mu\text{m}$ –149  $\mu\text{m}$  is approximately 1/3 of the total, and, as is clear from Table 1, the amount of unburned particles therein is approximately 13.4%.

Next, when comparing the combustion speed of the unburned particles within the medium fly ash that has been classified with the speed of the coal char, the former is generally slower, meaning that the combustion period for the unburned particles will be longer. Therefore, in order to efficiently combust and remove the unburned particles, it is necessary to increase the combustion speed of the unburned particles. Further, it is well known that when combustible solid particles in general, the combustion speed is proportional to the particle diameter in the chemical reaction rate-limiting step. In order to confirm the above, and as a result of finely crushing fly ash of 44  $\mu\text{m}$  and 149  $\mu\text{m}$  to be less than 44  $\mu\text{m}$  and then measuring the combustion speed of fine-

powder materials using a thermobalance, the inventors of this invention obtained the results shown in Figure 1 and confirmed that the chemical reaction speed is the rate-limiting step at temperatures of 900  $^{\circ}\text{C}$  or less. In Figure 1, the curve represented by the letter *a* is the fly ash as it is discharged from the coal boiler, *b* is the medium fly ash and *c* is the fine fly ash. Each shows the relationship between combustion temperature and combustion period.

According to these results, the combustion temperature of the fine fly ash is low in comparison to the others, and as the combustion period is also short, we confirmed the efficacy of particle classification on combustion temperature. Further, the ignition temperature of the unburned particles was, as shown in Table 2, lower for the fine fly ash, further confirming the efficacy of particle classification.

Table 2

	Particle Diameter ( $\mu\text{m}$ )	Ignition Temperature ( $^{\circ}\text{C}$ )
Fly ash discharged from the boiler	$d = 30$	525
Classified fly ash	$d > 149$	575
	$44 \leq d \leq 149$	555
	$d < 44$	525
Fine divided fly ash		495

Further, when classifying the medium fly ash, as the unburned particles were easily separated and the diameter of these particles was small, we confirmed that classification by particle diameter after particle crushing is effective in decreasing the amount of unburned particles to be treated. In this example of embodiment, the medium fly ash of particle diameter 44  $\mu\text{m}$ –149  $\mu\text{m}$  is finely crushed into fly ash of particle diameter less than or equal to 44  $\mu\text{m}$ , and when this is further separated into 10  $\mu\text{m}$ , as shown in the below Table 3, the amount of unburned particles within the fine fly ash with particle diameter 10  $\mu\text{m}$ –44  $\mu\text{m}$  is 3.5%, and the amount of unburned particles within the ultra-fine fly ash with particle diameter less than or equal to 10  $\mu\text{m}$  is 18.2%. Therefore, when classifying the ash in this area, it is possible to concentrate the unburned particles.

Table 3

	Particle Diameter ( $\mu\text{m}$ )	Unburned Particles (%)
Fine divided fly ash	$10 \leq d \leq 44$	3.5
	$d < 10$	18.2

Therefore, according to the results shown in Table 3, as the unburned particle amount of the 10  $\mu\text{m}$ -44  $\mu\text{m}$  fine fly ash is no more than 5%, it is possible to use this in fly ash cement as well as in other things, and further, by sending the remaining ultra-fine fly ash of 10  $\mu\text{m}$  or less into the fly ash apparatus, it is possible to reform the material by combusting the concentrated unburned particles therein. The amount of ultra-fine fly ash of 10  $\mu\text{m}$  or less to be sent into the modifying apparatus is on the scale of  $\frac{1}{4}$  the total amount of fly ash discharged from the coal boiler.

Also, the above results of the example of embodiment confirmed that there is a similar trend in different types of fly ash, and that it is possible to effectively perform modifying of the fly ash.

Next, we will explain the method and apparatus for fly ash according to this invention based on the example of embodiment illustrated in the figures.

The apparatus for fly ash shown in Figure 2 is constructed of two vertically long air current furnaces 1 and 2 that are arranged in parallel; a combustion duct 3 that connects the upper exit side of the primary air current furnace 1 and the lower input side of the secondary air current furnace 2; and a cooling apparatus 5 that is connected to the upper exit side of the secondary air current furnace 2 via the cyclone 4. Each air current furnace 1 and 2 is constructed of mixing chambers 6 and 7 that have an inverted cone shape with a large angle of repose on the lower half part of the chamber, and that have cylindrical combustion chambers 8 and 9 on the upper half of the chamber. In each combustion chamber 8 and 9, there are division circulation apparatus 10 and 11 in order to circulate one portion of the combusted fly ash within the air current furnaces 1 and 2. These division circulation apparatus 10 and 11 are constructed of small circulation cyclones 12 and 13; bunkers 14 and 15 that temporarily accumulate the fly ash; and cylindrical chutes 16 and 17 that draw the fly ash that falls from these bunkers 4 and 15 into the lower part of the combustion chambers 6 and 7. The circulation cyclones 12 and 13 are connected to the combustion duct 3 of the upper exit side of the primary air current

furnace 1 and the secondary air current furnace exhaust duct 18 of the upper exit side of the secondary air current furnace 2. Further, on the lower terminus of the mixing chamber 6 of the primary air current furnace 1, the jet air duct 20 that is branched from the combustion air supply duct 19 is connected in the perpendicular direction, and in the vicinity of this connection part, the swirl air duct 21 that is branched from the other part of the said combustion air supply duct 19 is connected helically to the side part of the mixing chamber 6. Further, on the midsection of the jet air duct 20, the fly ash supply pipe 23 is connected in order to supply ultra-fine fly ash from the hopper 22, and there is a supplementary burner 24 in the mixing chamber 6. On the lower terminus of the mixing chamber 7 of the secondary air current furnace 2 that is formed in the same manner as the said primary air current furnace 1, one edge of the combustion duct 3 is connected in the perpendicular direction, and in the vicinity of this connection, the swirl air duct 25 that is formed from the front portion of the said combustion air supply duct 19 is connected in the same manner as the above primary air current furnace 1. Further, there is a supplementary burner 26 inside the mixing chamber 7 that is set in the same manner as in the primary air current furnace 1.

In the fly ash modifying apparatus that is constructed in this way, the high-temperature air that passes through the combustion air supply duct 19 (for instance, the waste heat from the clinker cooling apparatus of a cement burning plant) swirls about the lower part of the primary air current furnace via the jet air duct 20 and the swirl air duct 21, and while swirling the fine-powder fly ash that was drawn into the central part of the jet air duct 20 from the fly ash supply pipe 23, it is jetted within the mixing chamber 6. In this case, the high-temperature air is sent into the inverted cone shaped mixing chamber 6 that has a large angle of repose while undergoing the action of both the jet air flow and the swirl air flow, which promotes the mixing of the fine-powder fly ash that is drawn into this flow as well as providing a swirling action to the fly ash such that it is possible to increase the accumulation period within the mixing chamber 6. The fine-powder fly ash that is mixed in this way moves within the combustion chamber 8, and here, the unburned particles within the fly ash are burned and then led into the circulation cyclone 12, where it

undergoes a division operation by the circulation cyclone 12. As a result of this division operation, one portion (approximately 50%) of this fly ash is discharged along with the combustion air from the combustion duct 3, and after the remainder of the fly ash is accumulated for a short period within the bunker 14, it falls into the chute 16, where it is recirculated by the combustion chamber 8 once again. By undergoing this circulation action, the unburned particles of the same size within the fly ash repeatedly undergo combustion, and gradually, the particle diameter of the unburned particles grows smaller to the point when, finally, they enter the combustion duct 3 from the circulation cyclone 12. At the edge of the combustion air supply duct 19 there is a fan for drawing in external air, and when using cold external air drawn in by this fan as the combustion air, it is preferable to use the supplementary burner 24 to provide heat within the furnace, and to keep the furnace internal temperature to be approximately 700 °C. Further, in the event that the unburned particles are not combusted even in this circulation action of the fly ash, and some large diameter unburned particles remain, it is possible to set up an unburned particle sampling apparatus (not shown) at the lower edge of the combustion chamber 6.

The fly ash discharged from the primary air current furnace 1 is led into the secondary air current furnace 2 along with the exhaust gas via the combustion duct 3, and after undergoing mixing by the combustion air supplied from the swirl air duct 25, it moves into the combustion chamber 9, where it undergoes combustion again. The fly ash after the unburned particles have undergone complete combustion through the action of the division circulation apparatus 11 is led into the cyclone 4 along with the exhaust gas via the secondary air current furnace exhaust duct 18, and after being separated from the exhaust gas, it is accumulated within the cooling apparatus 5. Then, after being cooled by thermal conversion with the cooling apparatus 27, it is discharged to the outside, where it can be used in a variety of applications. The exhaust gas discharged from the cyclone 4 is then led into the exhaust duct 28 that is connected to the upper part of the cyclone 4.

Figure 3 shows another example of embodiment of the apparatus according to this invention. In the same manner as the previous example of embodiment, there are two air current furnaces 1 and 2, which are arranged in parallel, and this apparatus combusts the unburned particles within the fly ash. However, this example of embodiment differs from the previous

example in that there is a division circulation apparatus 29 located between the primary air current furnace 1 and the secondary air current furnace 2. In other words, the division circulation apparatus 29 in this example of embodiment is constructed of a circulation cyclone 30 that is connected directly to the upper exit side of the primary air current furnace 1, a bunker 31 and a distribution chamber 32 that contains an opening and closing mechanism 33, and circulation paths 34 and 35 that extend to the mid-section of each jet air duct 20a and 20b of the primary air current furnace 1 and the secondary air current furnace 2 from the lower edge of this distribution chamber 32. The fine-powder fly ash that has undergone combustion within the primary air current furnace 1 is divided and accumulated within the circulation cyclone 30, and after it is temporarily accumulated within the bunker 31, it can be distributed into both the circulation paths 34 and 35 via the distribution chamber 32. The fly ash that has been distributed by the circulation path 34 is once again returned to the primary air current furnace 1, and is led again into the circulation apparatus 29 after undergoing combustion. Further, the unburned particles of the fly ash that has been distributed by the other circulation path 35 is completely combusted within the secondary air current furnace 2, and after accumulating within the cyclone 4, it is cooled in the cooling apparatus 5. The exhaust gas from the circulation cyclone 30 and the cyclone 4 is led into the exhaust duct 28. In this example of embodiment, the circulation of the fly ash that is returned to the primary air current furnace via the circulation path 34 is performed via adjustment of the opening and closing angle of the opening and closing mechanism 33 within the distribution chamber 32, but it is also possible to determine the circulation amount based on the amount of unburned particles within the reformed fly ash discharged from the cooling apparatus 5, and, for instance, when the amount of unburned particles is high, to increase the circulation amount and to increase the combustion in order to completely combust the unburned particles. In this example of embodiment, the division circulation apparatus 29 is located on the outer part of the air current furnaces 1 and 2, so the pressure drop within the air current furnaces 1 and 2 is lower in comparison to the previous example of embodiment, and it is possible to achieve efficacy in the adjustment of the circulation amount of the fly ash into the primary air current furnace 1.

The amount of unburned particles contained within the fly ash recovered from the cooling apparatus 5 of the modifying apparatus in the above example of embodiment can be reduced to as little as 0.5%, and it is possible to use it as fly ash cement as well as in other applications.

Figures 4 and 5 illustrate the two types of modifying apparatus in the above examples of embodiment when implemented within a cement burning plant. The combustion air supply duct 19 is connected to the cooling

apparatus 36 of the cement clinker, and not only is the approximately 700 °C hot air that is extracted from the cooling apparatus 5 used as combustion air for the unburned particles, but with the exhaust duct 28 of the modifying apparatus connected to the suspension preheater 37 at an appropriate location, the heat contained within the exhaust gas after combusting the fly ash can also be used in preheating the cement material. In this way, by including the modifying apparatus in a cement burning plant, it is possible to use the high temperature combustion air, and it is possible to greatly reduce the amount of fuel used in heating the combustion air by the supplementary burners 24 and 26 that are located within the air current furnaces of the modifying apparatus. Further, as it is possible to use the fly ash with extremely small particle diameter contained within the exhaust gas as one portion of the cement material, there is no need to use a special electric extractor, and as it is possible to recover and use the waste heat from the modifying apparatus in the suspension preheater 37, there is a large industrial advantage in using this apparatus.

As explained above, according to the fly ash modifying method in this invention, by classifying the fly ash discharged from a coal boiler, it is possible to greatly reduce the amount of unburned particles to be treated, and as it is possible to

economize on the fuel used in combusting these unburned particles, it is possible to reduce the size of the combustion furnace. Further, by classifying the ash in this way, this apparatus makes it possible to effectively use the total amount of fly ash discharged industrially.

Further, according to the modifying apparatus in this invention, the accumulation period for the unburned particles is increased, and by circulating these unburned particles, they are completely combusted, and so it is possible to make the unburned particles contained within the reformed fly ash into a highly smoothed product.

#### 4. Brief Explanation of the Drawings

Figure 1 is a graph showing the relationship between the combustion temperature and the combustion period of the unburned particles contained within the fly ash. Figure 2 is an explanatory drawing showing one example of embodiment of the modifying apparatus according to this invention. Figure 3 is an explanatory drawing showing another example of embodiment of the modifying apparatus. Figures 4 and 5 are explanatory drawings showing the example of embodiment where the modifying apparatus according to this invention has been included within a cement burning plant.

1 . . . primary air current furnace; 2 . . . secondary air current furnace; 6, 7 . . . mixing chamber; 8, 9 . . . combustion chamber; 10, 11, 29 . . . division circulation apparatus; 19 . . . combustion air supply duct; 20 . . . jet air duct; 21, 25 . . . swirl air duct; 28 . . . exhaust duct; 36 . . . cooling apparatus; 37 . . . suspension preheater.

Patent Applicant  
Ltd.

Representative, Attorney Akira TSUCHIBASHI  
[stamp: Attorney, Akira Tsuchibashi, Signatory]